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A survey of part of the city of Rensselaer, New York by aerial photographs with the use of altimeters

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Troy, New York; Rensselaer Polytechnic Institute

A SURVEY OF PART OF THE CITY OF RENSSELAER, NEW YORK BY AERIAL PHOTOGRAPHS WITH THE USE OF ALTIMETERS

by

LENSON WALKER GRAVES AND

OSCAR FRANCIS NICHOLSON

Comments by Bureau of Yards and Docks

(b) "A Survey of Part of the City of Rensselaer, New York, by Aerial Photographs with the use of Altimeters" by Lt. L. W. Graves, CEC, USN and Lt. O. F. Nicholson, CEC, USN . The thesis describes the use of altimeters in conjunction with photographic surveying. A procedure is developed for the use of these instruments and a typical survey is given. The results would have been more conclusive, had the check profile been extended for a greater distance over irregular terrain.

A SURVEY OF PART
OF THE CITY OF RENSSELAER, NEW YORK
BY AERIAL PHOTOGRAPHS WITH THE USE
OF ALTIMETERS.

A THESIS PRESENTED TO THE FACULTY
OF RENSSELAER POLYTECHNIC INSTITUTE
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR DEGREE OF
MASTER OF CIVIL ENGINEERING

BY

LENSON WALKER GRAVES

AND

OSCAR FRANCIS NICHOLSON

TROY, N.Y.

AUGUST, 1947

WE WISH TO EXPRESS APPRECIATION TO ALL THOSE WHO HAVE GIVEN US AID AND ADVICE IN OUR PROSECUTION OF THIS THESIS, AND ESPECIALLY DO WE THANK THE FOLLOWING: PROFESSOR H.O. SHARP, ACTING HEAD OF THE DEPARTMENT OF CIVIL ENGINEERING, RENSSELAER POLYTECHNIC INSTITUTE; INSTRUCTOR ROBERT PALMER, OF THE CIVIL ENGINEERING DEPARTMENT, RENSSELAER POLYTECHNIC INSTITUTE; AND THE CITY ENGINEER OF RENSSELAER, NEW YORK.

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INTRODUCTION

The principles of photographic surveying have been known for a long period, however, photogrammetry has received so much impetus in the last ten or fifteen years, that its age is taken as one of the youngest types of surveying.

The books written on surveying around the turn of the century usually contained a chapter on the methods of photographic surveying. These books show that the principles behind this method were developed fully at that time. The experts on photographic surveying seem to have vanished with the years because little mention or reference to such methods have been made in the recent books. One may be lead to believe that after the invention and early development of the camera, surveyors, intrigued by the instrument, adapted it to their own field and developed the methods of photographic surveying. The decline in interest in photographic surveying may possibly be attributed to the following: the reluctance of many surveying engineers to give up the old tried and true method, the limited field of use for this method, and the cost in equipment and supplies for this procedure.

Merriman and Wiggin's Civil Engineering Handbook makes the following statement about photographic surveying:

"A rapid method of locating topographic details for construction of small scale maps is afforded by photographic surveying. Best results are obtained where the country has

characteristic shapes, and is not too thickly wooded to afford good positions for taking the views."

We were introduced to this field of work in the course in Photogrammetry at Rensselaer Polytechnic Institute. In the classroom we worked with aerial photographs and found the work very interesting. The following summer we were introduced to the altimeter as a means for determining the elevation of a point by means of comparative readings. At the time, Instructor Robert Palmer was more or less experimenting with the instruments to check them and determine exactly what their possibilities might be. With a few ideas of our own and the able suggestions and assistance of Professor H.O. Sharp and Instructor Robert Palmer, we set out to develop our procedure.

The photographs for this survey were generously given by Fairchild Aerial Surveys, Inc. New York City, to Rensselaer Polytechnic Institute. They were flown just prior to the beginning of work on this thesis. In the selection of the photograph to be used for our work an effort was made to obtain the following: an altitude differential of 200 feet, a rugged piece of terrain, a wooded area, an open area and a densely populated section.

CONDUCT OF SURVEY

PRELIMINARY WORK

In planning the procedure, that we were to use in the field, we felt we might and probably would come across some points in the field that would be necessary to locate for accurate plotting of the contours and which could not be picked out on the photograph. Determining the elevation of these points presented no problem. We would use the altimeter the same as for other points that were easy to identify on the photograph.

We hoped to be able to solve the problem of distance and direction from a known point without having to employ a transit. We felt it might be possible to adapt some equipment that would be light enough to set up on the photograph in the field with this equipment we wanted to be able to determine distance and plot directly on the photograph. As we have stated above, the elevation would be determined the same as for other points. A plane table alidade could have been used, but we hoped to develop something especially for our work.

In thinking over what equipment we might adapt for our use, we decided that the Standard Navy Stadimeter might be the answer. We knew that it was used for greater ranges than we would need and that at sea a higher target than we would be able to handle was used.

We obtained the loan of a stadimeter in order to test

our theories in the field. The old standard model and a new simplified model were sent us. We hoped that by using a smaller target and shorter ranges, we might be able to calibrate the stadimeter for our own needs.

One day in the field testing the stadimeter convinced us that the work necessary to adapt the equipment to our work would not be worth the time involved. Even if we did adapt the stadimeter, it would not be any lighter or more accurate than a plane table alidade and a stadia-rod.

We concluded that if it became necessary to use any equipment besides the altimeter, we would use the plane table alidade. We were fortunate in that we did not find the need of locating any points in the photograph other than by the aid of land marks.

APPARATUS AND MATERIALS

All apparatus and material used in this thesis is the property of the Civil Engineering Department of Rensselaer Polytechnic Institute.

The equipment employed was:

(a) Two altimeters #93 and #94, manufactured by the Wallace and Tiernan Company.

(b) Level #140

(c) Level rod, stakes and miscellaneous surveying equipment.

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NOTES ON ALTIMETERS
from notes received from Instructor Robert Palmer.

"The precise surveying altimeter is a recently developed aneroid barometer of high sensitivity. By high sensitivity is meant that for small changes of elevation, there is a definite corresponding movement of the indicator hand: the instrument can be read to the nearest foot of elevation. The two chief manufacturers are the American Paulin System, and Wallace and Tiernan Company. The latter company produces one model with a range of 0 - 6000 feet, and another model with a range of 0 - 15000 feet. The instruments are graduated in feet, not inches or mm. of pressure. The price ranges from $200 - $300.

OPERATION - SINGLE BASE METHOD. Similar to aneroid barometer procedure. Requires the use of two altimeters, two thermometers and two watches. A point of known elevation is chosen as the base. First, the readings of the two instruments are compared at the base, over a 10 minute period, and a mean obtained for each. One instrument is then left at the base, and at 5 - minute intervals readings are taken on the altimeter and one of the thermometers. The other altimeter and thermometer (called the "field instrument") are taken to any points whose elevations are desired. At each point, readings are taken on the altimeter and thermometer, with the time of each reading also recorded. At the end of the day's work, the field instrument is brought back to the base and the two

instruments are compared again. To compute the elevation of any of the points, we take the mean of the readings on that point, and look up the readings that were taken on the base instrument at that same time. This makes allowance for weather-caused changes in atmospheric pressure during the day. If we now apply a correction for temperature to the difference between the base and field readings, we obtain the difference in elevation between the base and the point in question."

CONTROL

Before it was possible for us to begin our work in the field, we had to have some point of known elevation from which to start our work. In looking over the nine photographs we had to work with, we hoped that there might be a bench mark in the area. With this we would have an elevation to begin with. There was a triangulation station in one photograph, but the elevation was unknown.

Next, we went to the City Engineer's office in Rensselaer to see what he might have that would help us. From him, we were able to get several bench marks that were used for work in that city. However, the datum upon which these points were based was not known. They might have been based on the mean water level of the Hudson River at the city, or they may have been tied in with the Coast and Geodetic Surveys of the area.

Our next hope was to be able to find a bench mark on a highway in the area that could be used as a starting point.

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CONTROL

Before it was possible for us to begin our work in the field, we had to have some point of known elevation from which to start our work. In looking over the maps and photographs we had to work with, we hoped that there might be a bench mark in the area. With this we would have an elevation to begin with. There was a triangulation station in one photograph, but the elevation was unknown.

Next, we went to the City Engineer's office in [illegible] to see what he might have that would help us. From him, we were able to get several bench marks that were used for work in that city. However, the datum upon which these points were based was not known. They might have been based on the mean water level of the Indian River at the city, or they may have been tied in with the Coast and Geodetic Surveys of the area.

Our next hope was to be able to find a bench mark on a highway in the area that could be used as a starting point.

After a day going through several surveys in the area at the State Highway Department, we found two or three points that we might possibly use. When these points were investigated in the field, we decided that they were too far off the photographs to be useful.

So, even though we were not certain of the accuracy of the bench marks from the City of Rensselaer, we decided to go ahead with our work using one of their bench marks. We chose one on the corner of Broadway and Aiken Street that could be run up into the area of one of the photographs without too much difficulty.

SELECTING OF CONTROL BASES

We selected two well defined points on the map to act as control bases. These control bases were chosen at elevations which would enable us to use the altimeters with a range of fifty feet above or below the base and this would allow a coverage of the entire area in the photograph.

The determination of the elevation of the two control bases was accomplished by means of a level run from a point of known elevation at the intersection of Broadway and Aiken Street. The data of the level run is given below.

After a day going through several surveys in the office of the State Highway Department, we found two or three points that we might possibly use. When these points were investigated in the field, we decided that they were too far off the photographs to be usable.

So, even though we were not certain of the accuracy of the bench marks from the city of Chattanooga, we decided to go ahead with our work using one of their bench marks. It was then found that there was one on the corner of Broadway and Alton Street that could be run up into the area of one of the photographs without too much difficulty.

SELECTION OF CONTROL BASES

We selected two well defined points on the map to act as control bases. These control bases were chosen at elevations which would enable us to use the Kelsh plotter with a range of fifty feet above or below the base and this would give a coverage of the entire area in the photograph.

The determination of the elevation of the two control bases was accomplished by means of a level run from a bench mark of known elevation at the intersection of Broadway and Alton Street. The data of the level run is given below.

12 July, 1947

LEVEL NOTES FOR CONTROL BASES

STA.REFS.B.M.	PLUS SIGHT	H.I.	MINUS SIGHT	ELEV.	CORR.ELEV.
	2.08	21.83			19.75
TP_1	11.63	26.79	6.67	15.16	
TP_2	13.15	36.56	3.38	23.41	
TP_3	12.45	48.33	0.68	35.88	
TP_4	13.12	60.74	0.71	47.62	
TP_5	11.84	72.13	0.45	60.29	
TP_6	13.23	84.82	0.54	71.59	
TP_7	11.01	95.27	0.56	84.26	
BM_2	0.99	95.27	0.99	94.28	94.28
TP_8	0.28	84.52	11.03	84.24	
TP_9	0.32	72.84	12.00	72.52	
TP_{10}	0.03	60.30	12.57	60.27	
TP_{11}	0.02	48.07	12.25	48.05	
TP_{12}	0.62	35.90	12.79	35.28	
TP_{13}	2.15	26.90	11.15	24.75	
TP_{14}	5.44	20.40	11.94	14.96	
TP_{15}	5.53	22.45	3.48	16.92	
			2.74	19.71	

14 July, 1947

LEVEL NOTES FOR CONTROL BASES

STA.	PLUS SIGHT	H.I.	MINUS SIGHT	ELEV.	CORR. ELEV.
BM_2	10.86	105.14			94.28
TP_1	12.67	117.45	0.36	104.78	
TP_2	12.47	129.58	0.34	117.11	
TP_3	12.78	141.72	0.64	128.94	
TP_4	12.01	152.90	0.83	140.89	
TP_5	12.09	164.10	0.89	152.01	
TP_6	11.27	175.18	0.17	163.91	
TP_7	9.10	183.10	1.18	174.00	
TP_8	6.49	188.77	0.82	182.28	
BM_3	1.23	188.77	1.25	187.54	187.54
TP_9	0.95	180.42	9.30	179.47	
TP_{10}	1.39	171.42	10.39	170.03	
TP_{11}	0.00	158.71	12.71	158.71	
TP_{12}	0.57	147.43	11.85	146.86	
TP_{13}	1.07	137.03	11.47	135.96	
TP_{14}	0.39	124.91	12.51	124.52	
TP_{15}	0.30	113.36	11.85	113.06	
TP_{16}	1.10	101.94	12.52	100.84	
			7.62	94.32	

PLOTTING OF MAP AND CONTOUR DRAWING

The nine photographs donated by Fairchild Aerial Surveys Inc. were made in two sizes. One a 9" by 9" size or a scale of 600 feet to the inch, the other a 26" by 26" size or a scale of 200 feet to the inch. The sizes were ideal for our work because we used the 9" by 9" photograph for the field work and the 26" by 26" photograph for the actual contour plotting.

The small photograph was very easy to handle in the field whereas a large photograph would have been very cumbersome to use. The points for which the elevations were desired were usually easily identified on the photograph. Each point was given an index number and the altimeter reading and required information was recorded in the notes opposite the same number The information recorded in the field and at the control base were compared as shown in the data and computation section of this thesis. From this comparison the elevation of each of th index numbers was readily determined.

With the above information and the two maps the elevation for each of the index numbers was plotted on the large photograph. After all of the points of known elevation had been recorded on the large map we were then faced with the problem of contour drawing.

The problem of contour drawing was solved by assuming the changes in elevations to be fairly constant in the thick wooded areas. For this work we made a graph by means of which we were able to interpolate for the contours between elevation. In the open areas we could see the approximate path of the contours. Knowing the elevation of a number of points in the open area and the approximate path of the contours it was very easy to draw the contours in this area with the use of our interpolator.

CHECK BY TRIAL PROFILE

Upon completion of the field work with the altimeters and plotting the contours, a check was made to determine the accuracy of the map.

We proceeded with the check by going out to the area with a level and 100 foot chain. The line chosen for the check was near the center of the area. A run of ten stations or 1000 feet was desired, but we were limited in the points we could choose for the ends of the line. It was necessary that we could locate the points on the photograph. The line used was 8 + 12.5 stations in length and gave a difference in elevation of about 30 feet. By using that particular line, we were able to get a fairly accurate check without having to run the line through a wooded area that might prove too rough a terrain for the level work

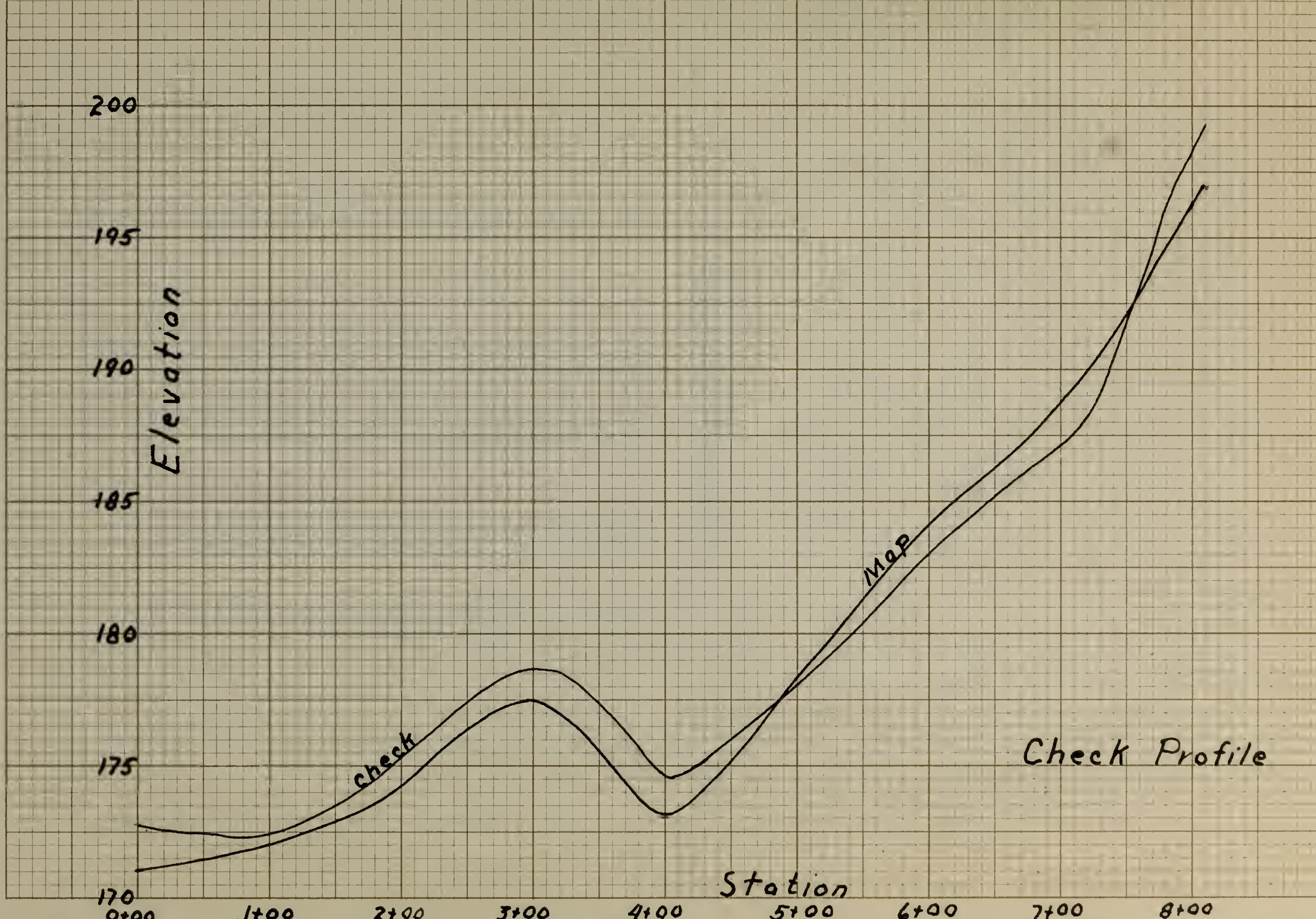
The results of the check are shown on the plot of the

profile. All stations checked within one-half of the contour interval.

29 July, 1947

CHECK PROFILE

STA.	PLUS SIGHT	H.I.	MINUS SIGHT	PROFILE	ELEV.
BM_2	4.00	191.50			187.50
TP_1	3.70	182.12	13.08		178.42
0-00	9.04	181.97	9.19		172.93
1-00				9.60	172.37
2-00				6.64	175.33
3-00				3.28	178.69
4-00	12.45	186.63	7.79		174.18
5-00				8.43	178.20
6-00	12.61	195.56	3.68		182.95
7-00	10.88	198.60	7.84		187.72
8-00	0.99	199.18	0.41		198.19
8-12.5			0.20		199.38
	53.67		41.99		187.50
	41.79		41.79		
	11.88				11.88



200
195
190
185
180
175
170
Elevation
Check
Map
Check Profile
Station
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00

DATA AND COMPUTATIONS

15 July

COMPARISON OF ALTIMETERS:

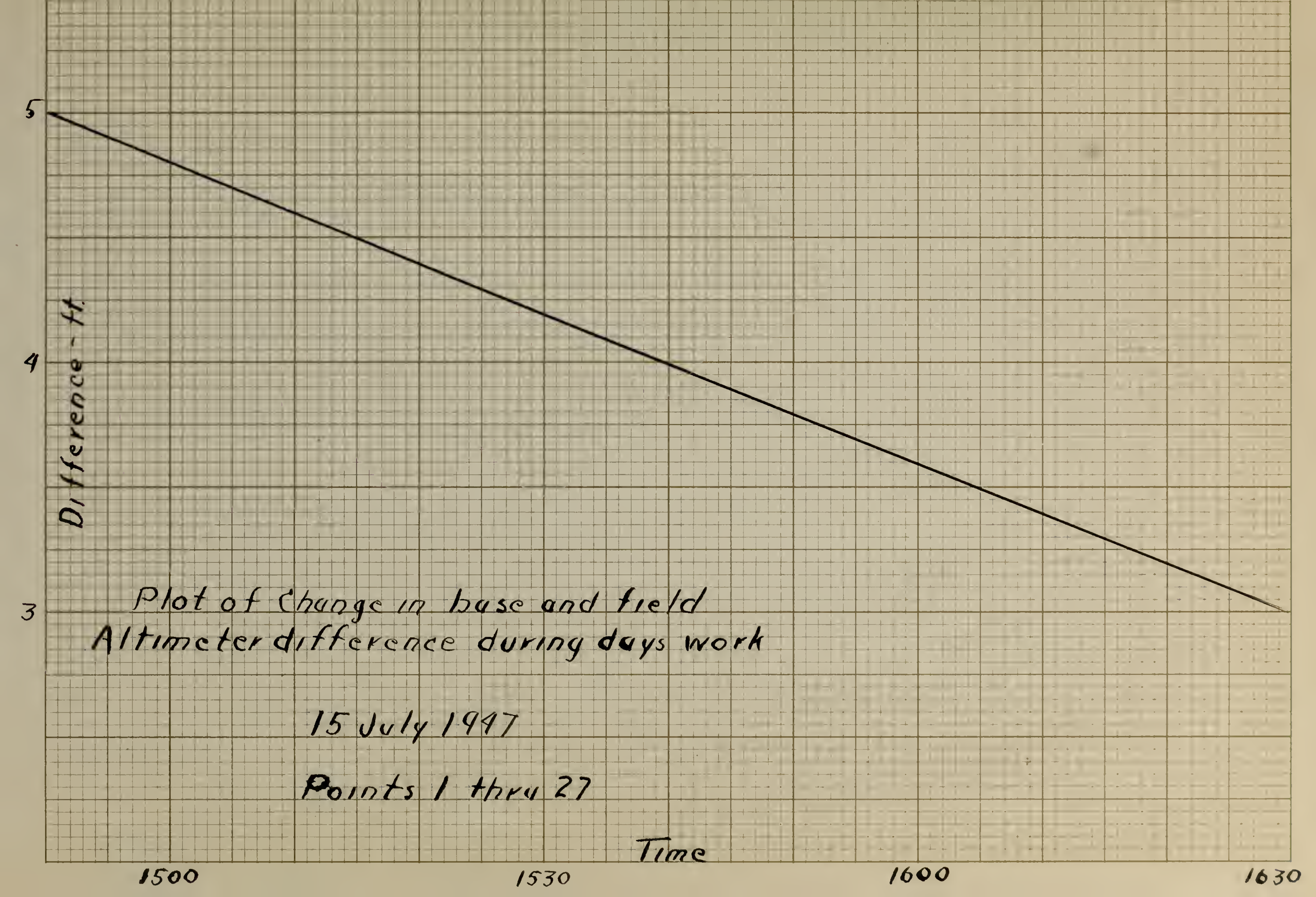
ALTIMETER# 93	START		END
READING	1278	1278	1252
TEMPERATURE	85		77
ALTIMETER# 94			
READING	1272	1273	1249
TEMPERATURE	83		78

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
1	86	1285	1440
2	86	1285	1440
3	86	1281	1444
4	86	1286	1450
5	83	1288	1455
6	88	1285	1505
7	88	1285	1508
8	90	1281	1511
9	90	1281	1514
10	90	1290	1517
11	90	1297	1525
12	89	1258	1530
13	90	1262	1535
14	90	1268	1537
15	90	1274	1539
16	90	1290	1542
17	90	1284	1546
18	87	1284	1550
19	87	1297	1600
20	85	1258	1605
21	83	1287	1611
22	80	1242	1625
23	80	1262	1629
24	80	1251	1634
25	80	1233	1637
26	80	1199	1642
27	80	1200	1645

STA. ALTIMETER

TIME	READING	TEMPERATURE
1440	1275	86
1445	1278	85
1450	1279	84
1455	1280	84
1500	1280	84
1505	1280	84
1510	1280	84
1515	1281	84
1520	1281	84
1530	1287	84
1535	1291	84
1540	1288	84
1545	1281	83
1550	1280	82
1555	1280	82
1600	1279	82
1605	1279	81
1610	1279	80
1615	1279	79
1620	1272	79
1625	1262	79
1630	1258	70
1635	1251	78
1640	1254	78
1645	1250	77


Plot of Change in base and field
Altimeter difference during days work
15 July 1947
Points 1 thru 27
Difference - ft.
5
4
3
Time
1500
1530
1600
1630

16 July

COMPARISON OF ALTIMETERS:

	START		END	
ALTIMETER #93				
READING	1374	1376	1401	1402
TEMPERATURE	88	88	82	82
ALTIMETER #94				
READING	1369	1370	1396	1397
TEMPERATURE	88	86	81	82

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
28	86	1357	1402
29	87	1330	1404
30	88	1351	1408
31	88	1362	1412
32	88	1351	1413
33	87	1363	1416
34	87	1361	1419
35	86	1331	1423
36	86	1379	1429
37	87	1350	1434
38	88	1371	1438
39	87	1351	1441
40	85	1372	1444
41	86	1359	1449
42	84	1377	1452
43	84	1380	1455
44	83	1371	1502
45	82	1381	1505
46	81	1361	1509
48	81	1368	1515
49	82	1345	1519
50	82	1370	1529
51	80	1372	1536
52	81	1369	1539
53	81	1332	1542
54	81	1367	1546

STA. ALTIMETER

TIME	READING	TEMPERATURE
1400	1378	87
1404	1380	87
1410	1372	86
1415	1371	86
1420	1371	85
1425	1372	85
1430	1378	85
1435	1379	85
1440	1378	85
1445	1372	84
1450	1378	84
1455	1378	84
1500	1379	83
1505	1380	82
1510	1376	81
1515	1379	81
1520	1389	81
1525	1390	81
1530	1394	80
1540	1394	80
1545	1398	80

18 July

COMPARISON OF ALTIMETERS:

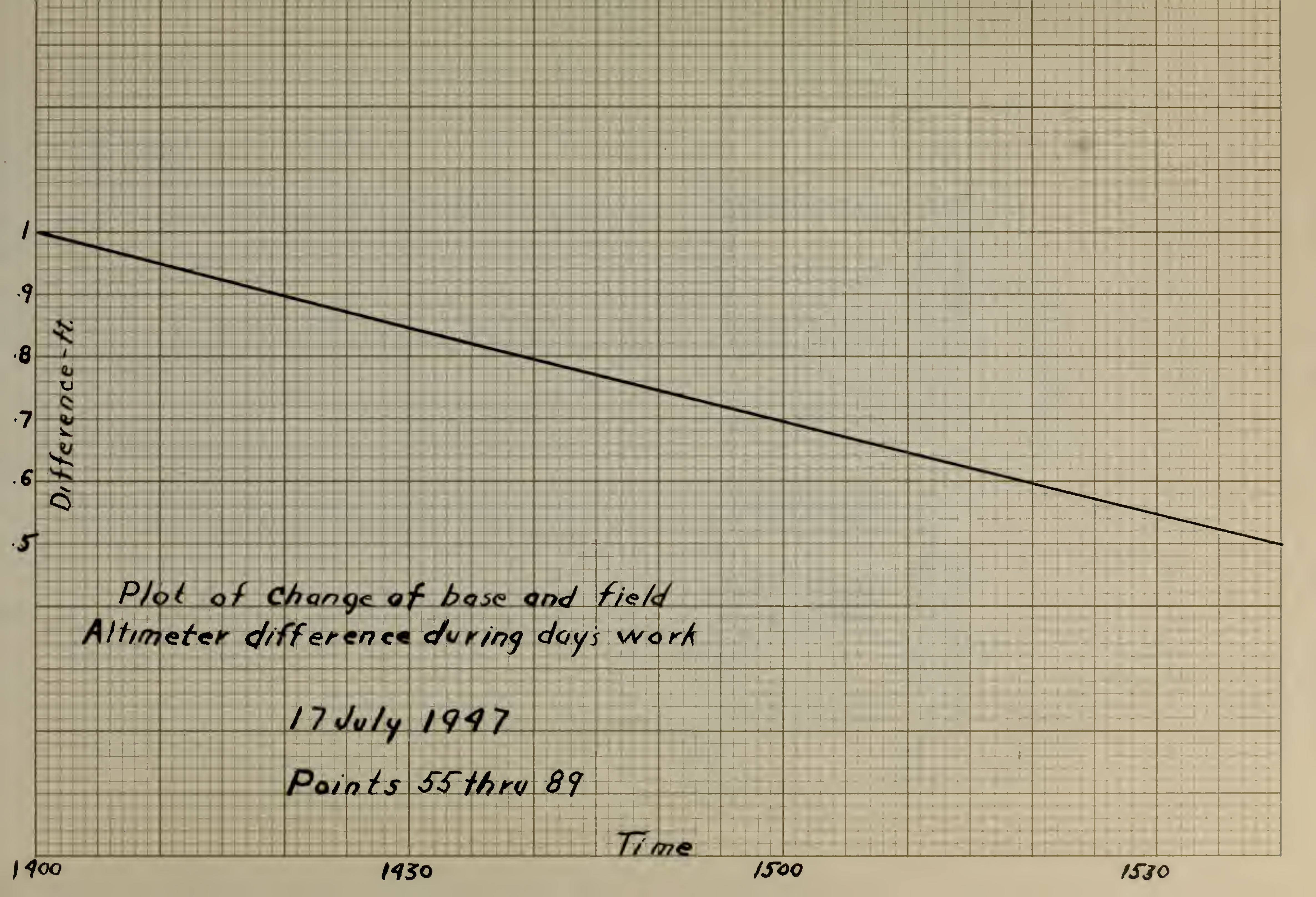
ALTIMETER #93	START		END
READING	1486	1488	1504
TEMPERATURE	86	86	85
ALTIMETER			
READING	1480	1481	1498
TEMPERATURE	86	86	81

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
55	86	1460	1349
56	86	1464	1352
57	87	1450	1354
58	88	1458	1358
59	88	1459	1401
60	88	1442	1404
61	89	1442	1409
62	89	1458	1412
63	89	1451	1415
64	89	1485	1418
65	88	1491	1422
66	89	1480	1425
67	90	1501	1430
68	89	1501	1435
69	89	1519	1440
70	90	1512	1445
71	91	1452	1452
72	86	1512	1459
73	90	1519	1504
74	91	1539	1509
75	92	1525	1540
76	92	1542	1544
77	92	1540	1547
78	93	1522	1554
79	93	1495	1559
80	90	1498	1605
81	90	1460	1608

STA. ALTIMETER

TIME	READING	TEMPERATURE
1345	1489	86
1350	1489	86
1355	1491	87
1400	1495	87
1405	1498	88
1410	1499	88
1415	1502	88
1420	1504	88
1425	1507	88
1430	1508	88
1435	1509	88
1440	1511	88
1445	1514	88
1450	1512	88
1455	1512	88
1500	1522	88
1505	1529	89
1510	1527	90
1515	1521	91
1520	1519	91
1525	1520	91
1530	1501	91
1535	1521	90
1540	1523	90
1545	1532	90
1550	1536	89
1555	1538	89


1
.9
.8
.7
.6
.5
Difference - ft.
Plot of change of base and field
Altimeter difference during days work
17 July 1947
Points 55 thru 89
Time
1900
1930
1500
1530

18 July cont.

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
82	87	1528	1612
83	85	1505	1616
84	85	1510	1619
85	85	1498	1622
86	85	1471	1625
87	85	1450	1627
88	84	1451	1630
89	83	1458	1632

STA. ALTIMETER

TIME	READING	TEMPERATURE
1600	1532	89
1605	1531	89
1610	1535	88
1615	1541	88
1620	1539	88
1625	1539	86
1630	1531	85
1635	1530	84

21 July

COMPARISON OF ALTIMETERS:

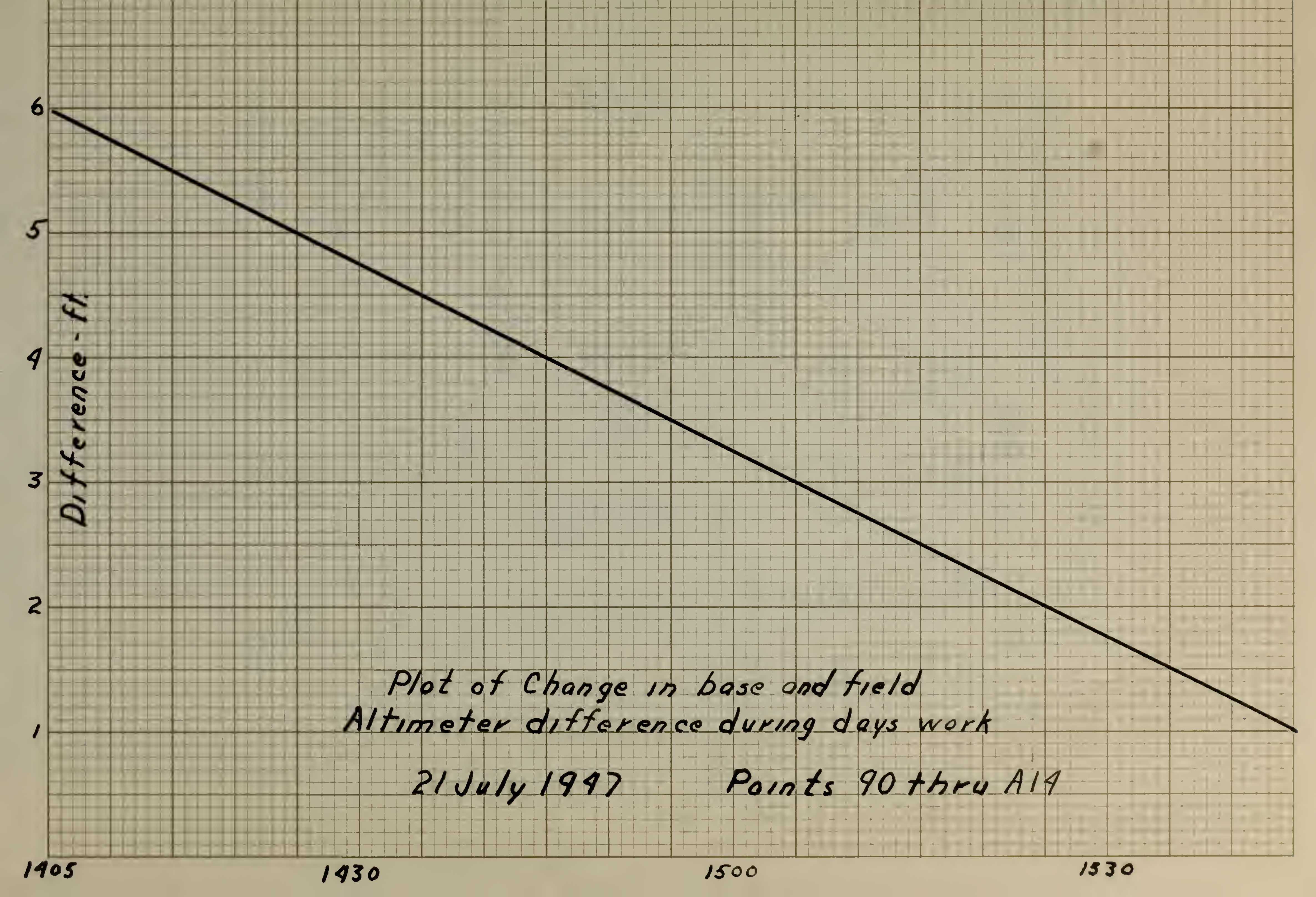
ALTIMETER #93	START		END	
READING	1212	1218	1231	1232
TEMPERATURE	83	85	94	93
ALTIMETER #94				
READING	1208	1210	1230	1230
TEMPERATURE	84	88	88	88

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
90	91	1218	1356
91	90	1193	1358
92	85	1184	1402
93	84	1200	1405
94	84	1258	1408
95	84	1179	1414
96	84	1188	1420
97	84	1294	1435
98	85	1289	1443
99	85	1272	1446
A1	85	1279	1449
A2	84	1246	1453
A3	84	1281	1459
A4	84	1276	1507
A5	85	1240	1513
A6	84	1221	1518
A7	85	1268	1530
A8	85	1224	1535
A9	85	1179	1539
A10	86	1202	1544
A11	87	1189	1546
A12	87	1181	1549
A13	87	1171	1551
A14	88	1215	1555
A15			

STA. ALTIMETER

TIME	READING	TEMPERATURE
1355	1218	88
1400	1214	91
1405	1216	92
1410	1212	93
1415	1212	93
1420	1212	94
1425	1213	96
1430	1220	98
1435	1220	100
1440	1219	100
1445	1219	100
1450	1219	100
1455	1221	98
1500	1222	98
1505	1222	97
1510	1223	97
1515	1228	96
1520	1225	95
1525	1228	94
1530	1228	94
1535	1228	95
1540	1228	95
1545	1229	95
1550	1228	95
1555	1226	95


Plot of Change in base and field
Altimeter difference during days work
21 July 1947
Points 90 thru A14
Difference - ft.
6
5
4
3
2
1
1405
1430
1500
1530

23 July

COMPARISON OF ALTIMETERS:

ALTIMETER #93	START		END	
READING	1200	1200	1200	1199
TEMPERATURE	82	79	80	80
ALTIMETER #94				
READING	1199	1199	1194	1194
TEMPERATURE	78	79	82	82

FIELD ALTIMETER

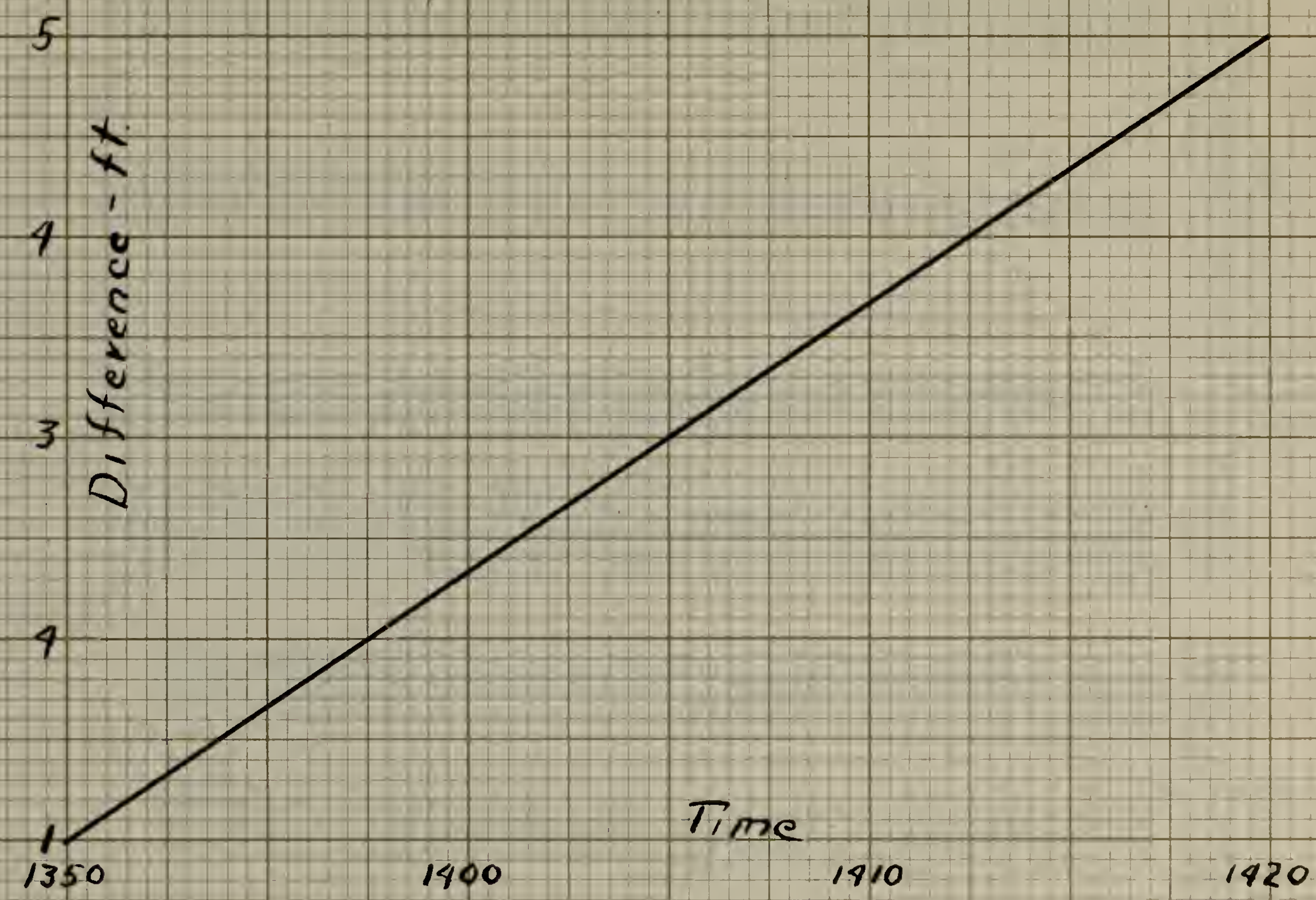
STA.	TEMPERATURE	READING	TIME
A15	81	1213	1359
A16	83	1142	1405
A17	83	1211	1410
A18	83	1211	1415
A19	83	1211	1417

STA. ALTIMETER

TIME	READING	TEMPERATURE
1350	1199	78
1355	1199	78
1400	1196	79
1405	1193	80
1410	1196	81
1415	1195	81
1420	1196	80

COMPARISON OF ALTIMETERS:

ALTIMETER #93	START		END	
READING	1110	1111	1062	1062
TEMPERATURE	81	85	84	83
ALTIMETER #94				
READING	1104	1104	1056	1059
TEMPERATURE	82	85	80	80



Plot of Change in base and field
Altimeter difference during days work

23 July 1947 Points A15 thru A19

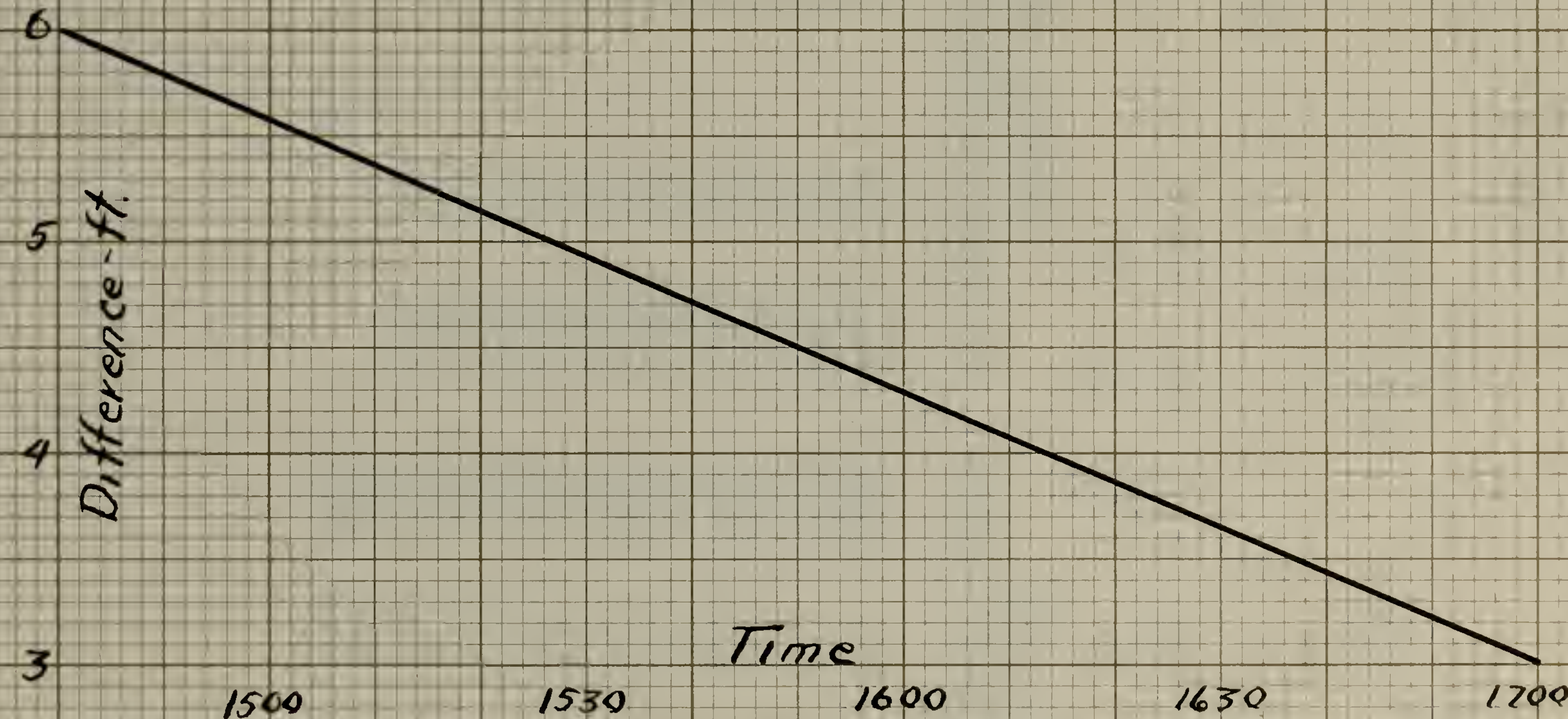
23 July cont.

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
A20	84	1139	1445
A21	86	1041	1452
A22	88	1052	1455
A23	87	1072	1500
A24	88	1030	1508
A25	88	1038	1515
A26	90	1049	1520
A27	91	1031	1523
A28	91	1022	1525
A29	90	1041	1530
A30	89	1049	1533
A31	89	1049	1535
A32	88	1031	1538
A33	88	1025	1545
A34	88	1044	1550
A35	86	1047	1555
A36	86	1039	1557
A38	86	1040	1603
A39	86	1035	1607
A40	85	1076	1612
A41	83	1108	1615
A42	83	1128	1620
A43	82	1118	1623
A44	82	1094	1625
A45	83	1059	1630
A46	82	1023	1635
A47	82	1069	1640
A48	81	1000	1642
A49	81	1040	1645
A50	80	1040	1648
A51	80	1071	1653
A52	81	1088	1658

STA. ALTIMETER

TIME	READING	TEMPERATURE
1440	1111	85
1445	1109	89
1450	1108	91
1455	1109	93
1500	1108	94
1505	1105	95
1510	1103	96
1515	1101	96
1520	1103	96
1525	1103	96
1530	1103	96
1535	1102	96
1540	1100	97
1545	1100	97
1550	1100	96
1555	1099	95
1600	1092	94
1605	1090	94
1610	1088	93
1615	1082	91
1620	1080	89
1625	1079	87
1630	1074	87
1635	1072	86
1640	1071	85
1645	1070	85
1650	1068	85
1655	1068	85
1700	1065	84
1705	1063	84



Plot of Change in base and field
Altimeter difference during days work

23 July 1947   Points A20 thru A52

24 July

COMPARISON OF ALTIMETERS:

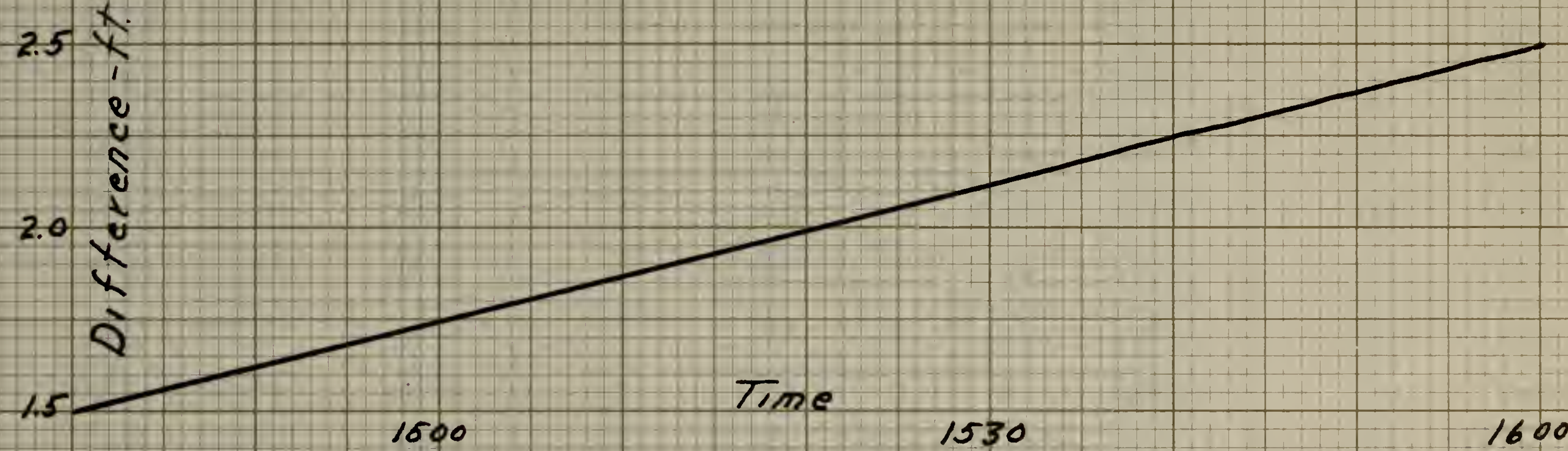
ALTIMETER #93	START		END	
READING	870	871	871	872
TEMPERATURE	83	83	96	94
ALTIMETER #94				
READING	869	869	868	870
TEMPERATURE	85	85	88	89

FIELD ALTIMETER

STA.	TEMPERATURE	READING	TIME
A53	84	823	1445
A54	83	862	1458
A55	82	922	1503
A56	82	931	1507
A57	82	931	1512
A58	82	931	1512
A59	81	951	1515
A60	81	949	1520
A61	81	950	1523
A62	82	970	1526
A63	82	952	1531
A64	86	921	1545
A65	85	906	1548
A66	85	831	1552
A67	86	820	1555

STA. ALTIMETER

TIME	READING	TEMPERATURE
1440	871	84
1445	871	84
1450	871	85
1455	870	88
1500	869	88
1505	869	87
1510	869	87
1515	868	87
1520	867	88
1525	869	90
1530	871	92
1535	871	91
1540	869	92
1545	869	91
1550	869	90
1555	869	90
1600	869	90



Plot of Change in base and field
Altimeter difference during days work

24 July 1947 Points 28 thru 54

base elevation 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNAJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
1	1440	1278	1285	7	86	.5	7.5	195.0	5	200.0
2	1442	1276	1285	9	86	.6	9.6	197.1	5	202.1
3	1444	1277	1281	4	85.5	.3	4.3	191.8	5	196.8
4	1450	1279	1286	7	85	.5	7.5	195.0	5	200.0
5	1455	1280	1288	8	83.5	.5	8.5	196.0	4.8	200.8
6	1505	1280	1285	5	86	.4	5.4	192.9	4.7	197.6
7	1508	1280	1285	5	86	.4	5.4	192.9	4.7	197.6
8	1511	1280	1281	1	87	.1	1.1	188.6	4.6	193.2
9	1514	1281	1281	0	87	0	0	187.5	4.5	192.0
10	1517	1281	1290	9	87	.9	9.6	197.1	4.5	201.6
11	1525	1284	1297	13	87	1.0	14.0	201.5	4.3	205.8
12	1530	1287	1258	29	88	2.2	26.8	160.7	4.2	164.9
13	1535	1291	1262	29	87	2.1	26.9	160.6	4.1	164.7
14	1537	1290	1268	22	87	1.6	20.4	167.1	4.1	171.2
15	1539	1289	1274	15	87	1.1	13.9	173.6	4.0	177.6
16	1542	1286	1290	4	87	.3	4.3	191.8	3.9	195.7
17	1546	1281	1284	3	86.5	.3	3.2	190.7	3.9	194.6

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
18	1550	1280	1284	4	84.5	.3	4.3	191.8	3.8	195.6
19	1600	1279	1297	18	84.5	1.3	19.3	206.8	3.6	210.4
20	1605	1279	1252	27	83	1.8	25.2	162.3	3.5	165.8
21	1611	1279	1287	8	81.5	.5	8.5	196.0	3.4	199.4
22	1625	1262	1242	20	79.5	1.2	18.8	168.7	3.1	171.8
23	1629	1259	1262	3	75	.2	3.2	190.7	3.0	193.7
24	1634	1252	1231	21	79	1.2	19.8	167.7	3.0	170.7
25	1637	1252	1233	19	79	1.1	17.9	169.6	3.0	172.6
26	1642	1253	1199	54	79	3.1	50.9	136.6	3.0	139.6
27	1645	1250	1200	50	78.5	2.8	47.2	140.3	2.0	142.3
28	1402	1379	1357	22	86.5	1.6	20.4	167.1	1.0	168.1
29	1405	1380	1330	50	87	3.6	46.4	141.1	1.0	142.1
30	1408	1375	1351	24	87	1.7	22.3	165.2	1.0	166/1
31	1412	1371	1362	9	87	.7	8.3	179.2	.9	180.1
32	1415	1371	1351	20	87	1.5	18.5	169.0	.9	100.1
33	1416	1371	1367	18	86.5	1.3	16.7	170.8	.9	171.7

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	COR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
34	1419	1371	1361	10	86	.7	9.2	178.2	.9	179.1
35	1423	1372	1331	41	85.5	3.9	37.1	150.4	.9	151.3
36	1429	1377	1379	2	85.5	.1	1.9	189.4	.9	190.3
37	1434	1378	1350	28	86	2.0	26.0	161.5	.8	162.3
38	1438	1378	1371	7	86.5	0.5	6.5	181.0	.8	181.8
39	1441	1376	1351	25	86	1.8	23.2	164.3	.8	165.1
40	1444	1373	1372	1	84.5	.1	.9	186.6	.8	187.4
41	1449	1377	1359	18	85	1.2	16.8	170.7	.8	171.5
42	1452	1378	1377	1	84	.1	.9	186.6	.7	187.3
43	1455	1378	1380	2	84	.1	1.9	189.4	.7	190.1
44	1502	1379	1371	8	83	.5	7.5	180.0	.7	187.3
45	1505	1380	1381	1	82	.1	.9	186.6	.7	187.3
46	1509	1377	1361	16	81	1.0	15.0	172.5	.7	173.2
47	1513	1378	1362	16	81	1.0	15.0	172.5	.6	173.1
48	1515	1379	1359	20	81	1.2	18.8	168.7	.6	169.3

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	TEMP MEAN	TEMP CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
49	1519	1387	1345	42	81.5	2.6	39.4	148.1	.6	148.7
50	1529	1392	1370	22	81	1.3	20.7	166.8	.5	167.4
51	1536	1394	1372	22	80	1.3	20.7	166.8	.5	167.3
52	1539	1394	1369	25	80.5	1.5	23.5	164.0	.5	164.5
53	1542	1395	1332	63	80.5	3.8	59.2	128.3	.5	128.8
54	1546	1398	1364	31	80.5	1.9	29.1	158.4	.5	158.9
55	1349	1489	1460	29	86	2.0	27.0	160.5	6	166.5
56	1352	1490	1464	26	86	1.8	24.2	163.3	6	169.3
57	1354	1492	1450	42	87	3.0	39.0	148.5	6	154.5
58	1358	1494	1458	36	87.5	2.6	33.4	154.1	6	160.1
59	1401	1495	1459	36	87.5	2.6	33.4	154.1	6	160.1
60	1404	1497	1442	55	88.5	4.1	50.9	136.6	6	142.6
61	1409	1499	1442	57	88.5	4.3	52.7	134.8	6	140.8
62	1412	1500	1458	42	88.5	3.2	38.8	148.7	6	154.7
63	1415	1502	1451	51	88.5	3.8	47.2	140.3	6	146.3

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
64	1418	1503	1485	18	88.5	1.4	16.6	170.9	6	176.9
65	1422	1505	1491	14	88.5	1.0	13.0	174.5	6	180.5
66	1425	1507	1480	27	88.5	2.0	25.0	162.5	6	168.5
67	1430	1508	1501	7	89	.5	6.5	181.0	6	187.0
68	1435	1509	1501	8	88.5	.6	7.4	180.1	6	186.1
69	1440	1511	1519	8	88.5	.6	8.6	196.1	6	202.1
70	1445	1514	1512	2	89	.2	1.8	185.7	6	191.7
71	1452	1512	1452	60	89.5	4.7	55.3	132.2	6	138.2
72	1459	1520	1512	8	87	.6	7.4	180.1	6	186.1
73	1504	1524	1519	5	89	.4	4.6	182.9	6	188.9
74	1509	1527	1539	12	90.5	1.0	13.0	200.5	6	206.5
75	1540	1523	1525	2	91	.2	2.2	189.7	6	195.7
76	1544	1570	1542	12	91	1.0	13.0	200.5	6	206.5
77	1547	1574	1540	6	90.5	.5	6.5	194.0	6	200.0

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
78	1554	1538	1522	16	91	1.3	14.7	172.8	6	178.8
79	1559	1533	1495	38	91	3.1	34.9	152.6	6	158.6
80	1605	1531	1498	33	89.5	2.6	30.4	157.1	6	163.1
81	1608	1534	1460	74	89	5.6	68.4	119.1	6	125.1
82	1612	1538	1528	10	87.5	7.2	2.8	184.7	6	190.7
83	1616	1541	1505	36	86.5	2.6	33.4	154.1	6	160.1
84	1619	1539	1510	29	86.5	2.1	26.9	160.6	6	166.6
85	1622	1539	1498	41	86.5	3.0	38.0	149.5	6	155.5
86	1625	1539	1471	68	85.0	4.7	63.3	124.2	6	130.2
87	1627	1535	1450	85	85.0	5.9	79.1	108.4	6	114.4
88	1630	1531	1451	80	84.5	5.5	74.5	113.0	6	119.0
89	1632	1530	1458	72	83.5	4.7	67.3	120.2	6	126.2

BASE ELEVATION 92.3

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
90	1356	1217	1218	1	89.5	.1	1.1	93.4	6	99.4
91	1358	1216	1198	18	90	1.4	16.6	75.7	6	81.7
92	1402	1217	1184	33	88	2.5	30.5	61.8	6	67.8
93	1405	1218	1200	18	88	1.4	16.6	75.7	6	81.7
94	1408	1214	1258	44	88	3.3	47.3	139.6	5.8	145.4
95	1414	1212	1179	33	88.5	2.5	30.5	61.8	5.5	67.3
96	1420	1212	1188	24	89	1.8	22.2	70.1	5.2	75.3
97	1435	1220	1294	74	92	6.1	80.1	172.4	4.5	176.9
98	1443	1219	1289	70	92.5	5.9	75.9	168.2	4.1	172.3
99	1446	1219	1272	53	92.5	4.4	57.4	149.7	3.9	153.6
A1	1449	1219	1279	60	92.5	5.0	65.0	157.3	3.8	161.6
A2	1453	1220	1246	26	91.5	2.2	28.2	120.5	3.6	124.1
A3	1459	1222	1281	59	91	4.8	63.8	156.1	3.3	159.4
A4	1507	1223	1276	53	90.5	4.3	57.3	149.6	2.9	152.5

A

BASE ELEVATION 92.3

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
A5	1513	1226	1240	14	90.5	1.1	15.1	107.4	2.6	110.0
A6	1518	1226	1221	5	89.5	.4	4.6	87.7	2.3	90.0
A7	1530	1228	1268	40	89.5	3.1	43.1	135.4	1.8	137.2
A8	1535	1228	1224	4	90.0	.3	3.7	88.6	1.5	90.5
A9	1539	1228	1179	49	90.0	3.9	45.1	47.2	1.3	48.5
A10	1544	1229	1202	27	90.5	2.2	24.8	67.5	1.1	68.6
A11	1546	1229	1189	40	91.0	3.2	36.8	55.5	1	56.1
A12	1549	1228	1181	47	91	3.8	43.2	49.1	1	50.1
A13	1551	1228	1171	57	91	4.6	52.4	39.9	1	40.1
A14	1555	1226	1215	11	91.5	.9	10.1	82.2	1	83.2

BASE ELEVATION 187.5

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
A15	1359	1197	1213	16	79.5	.9	16.9	204.4	2.2	206.6
A16	1405	1193	1142	51	81.5	3.0	48.0	139.5	3.0	142.5
A17	1410	1196	1211	15	82.0	1.0	16.0	203.5	3.7	207.2
A18										207.2
A19										207.2

BASE ELEVATION 92.3

A20	1445	1109	1139	30	86.5	2.1	32.1	124.4	5.9	130.3
A21	1452	1108	1041	67	89.0	5.1	61.9	30.4	5.7	36.1
A22	1455	1109	1052	57	90.5	4.6	52.4	39.9	5.7	45.6
A23	1500	1108	1072	36	90.5	2.9	33.1	59.2	5.6	64.8
A24	1508	1104	1030	74	92.0	6.1	67.9	24.4	5.4	29.8
A25	1515	1101	1038	63	92.0	5.2	57.8	34.5	5.2	39.7
A26	1520	1103	1042	54	93.0	4.6	49.4	42.9	5.1	48.0

BASE ELEVATION 92.3

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
A27	1523	1103	1031	72	93.5	6.2	65.8	26.5	5.1	31.6
A28	1525	1103	1022	81	93.5	7.0	74.0	18.3	5.0	23.3
A29	1530	1103	1041	62	93.0	5.3	56.7	35.6	4.9	40.5
A30	1533	1102	1049	53	93.0	4.5	48.5	43.8	4.8	48.6
A31										48.6
A32	1538	1101	1031	70	92.5	5.9	64.1	28.2	4.7	32.9
A33	1545	1100	1025	75	92.5	6.3	69.7	22.6	4.6	27.2
A34	1550	1100	1044	56	92.0	4.6	51.4	40.9	4.5	45.4
A35	1555	1099	1047	52	90.5	4.1	47.9	44.4	4.4	48.8
A36	1557	1096	1039	57	90.5	4.5	52.5	39.8	4.3	44.1
A37										44.1
A38	1603	1091	1040	51	90.0	4.0	47.0	45.3	4.2	49.5
A39	1607	1089	1035	54	90.0	4.3	49.7	42.6	4.1	46.7
A40	1612	1086	1076	10	88.5	7.4	2.6	89.7	4.0	93.7

BASE ELEVATION 92.3

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
A41	1615	1082	1108	26	87.0	1.9	27.9	120.2	4.0	124.0
A42	1620	1080	1128	48	86.0	3.4	51.4	143.7	3.8	147.5
A43	1623	1080	1118	38	85	2.6	40.6	132.9	3.8	136.7
A44	1625	1079	1094	15	84.5	1.0	16.0	108.3	3.7	112.0
A45	1630	1074	1059	15	85.0	1.0	14.0	78.3	3.6	81.9
A46	1635	1072	1023	49	84.0	3.2	45.8	46.5	3.5	50.0
A47	1640	1071	1069	2	83.5	.1	1.9	90.4	3.4	93.8
A48	1642	1071	1000	71	83.0	4.6	66.4	25.9	3.4	29.3
A49	1645	1070	1040	30	83.0	2.0	28.0	64.3	3.3	67.6
A50	1648	1069	1040	29	82.5	1.9	27.1	65.2	3.2	68.4
A51	1653	1068	1071	3	82.5	.2	3.2	95.5	3.1	98.6
A52	1658	1066	1088	22	82.5	1.4	23.4	115.7	3.0	118.7
A53	1445	871	823	48	84.5	3.3	44.7	47.6	1.5	49.1
A54	1458	869	862	7	85.5	.5	6.5	85.8	1.7	87.5

BASE ELEVATION 92.3

STA.	TIME	STATION ALTIMETER	FIELD ALTIMETER	DIFF. ALT. READING	MEAN TEMP.	TEMP. CORR.	CORR. DIFF.	UNADJUSTED ELEVATION	CLOSURE ADJUSTMENT	ADJUSTED ELEVATION
A55	1503	869	922	53	84.5	3.6	56.6	148.9	1.8	150.7
A56	1507	869	931	62	84.5	4.4	66.4	158.7	1.8	160.5
A57	1510	869	940	71	84.5	4.9	75.9	168.2	1.9	170.1
A58	1512	869	931	62	84.5	4.4	66.4	158.7	1.9	160.6
A59	1515	868	951	83	84.0	5.9	88.9	181.2	1.9	183.1
A60	1520	867	949	82	84.5	5.9	87.9	180.2	2.0	182.2
A61	1523	868	950	82	85.0	5.9	87.9	180.2	2.0	182.2
A62	1526	869	970	101	86.0	7.4	108.4	200.7	2.1	202.8
A63	1531	871	952	81	87.0	6.0	87.0	179.3	2.1	181.4
A64	1545	869	921	52	88.5	4.0	56.0	148.3	2.3	150.6
A65	1546	869	906	37	87.5	2.7	39.7	132.0	2.4	134.4
A66	1552	869	831	38	87.5	2.7	35.3	57.0	2.4	59.4
A67	1555	869	820	49	88.0	3.7	45.2	47.0	2.5	49.5

RESULTS AND CONCLUSIONS

COSTS:

Of interest to anyone making a survey, or to anyone who should like to do a similar thesis, is the cost of equipment and materials.

EQUIPMENT: (not including usual surveying equipment)
Altimeters cost from $200 - $300

MATERIAL:

The photographs for this thesis were given by Fairchild Aerial Surveys, Inc., but, the cost for such work varies from time to time and a definite price could not be set. Practically all the equipment and much of the material was graciously loaned us by the Civil Engineering Department of the Institute.

TIME CONSUMED IN THE SURVEY:

Not only the cost, but also the time consumed is of interest to anyone thinking of conducting a survey by a special means. The following fepresents the approximate amount of time used by the authors practically unassisted.

Preliminary reconnaissance	24 hours
Running control	8 hours
Elevations Determinations	32 hours
Computations	32 hours
Drawing and inking contours	38 hours
Running a check profile	4 hours
Total	138 hours

This represents 276 man hours for the complete mapping of approximately 530 acres.

The results for this type of survey are very good as shown by the check profile. There were no points having more than one half contour interval variation in elevation. This satisfies the specification that ninety percent of the points be within one half contour interval of the check profile. We do not expect to find such accuracy throughout the photograph due to the very rugged terrain. In sections the area was thick woods with a drop of about fifteen feet per foot, in this area the contour plotting was a guess but plotting by any other means would have been an impossibility. We believe this method of contour plotting to be a very feasable system for use in rough terrain or in thickly settled areas where other means would or could not be employed and this would be a very good method of contour plotting in all types of topography if speed was desired.

The main disadvantage of this procedure were the computations which were simple but they were a time consumer. We suggest a complete elimination of these computations by the use of the two base method and a converter developed by Instructor Robert Palmer of Rensselaer Polytechnic Institute. We would have employed this system but a party of three is required. An explanation of the procedure follows:

TWO BASE METHOD. Requires three altimeters, three watches, no thermometers unless additional checking is desired. Also, requires two points of known elevation called upper and lower base respectively. The upper base should be higher and the

lower base lower than any of the points whose elevation is desired. First, the readings of the three instruments are observed at the lower (or upper) base over a 10-minute period, for comparison. Then one of the other two instruments is taken to the other base. Both base instruments are read at 5-minute intervals from then on, while the third (field) instrument is read at each of the points where elevation is desired, with time recorded. At the end of the day's work, the three instruments are brought back together at the lower base for comparison. In computing the elevation of any of the points, we look up the readings of the upper base and lower base at the moment the readings were taken on the point in question. It will be noticed that the difference between upper and lower base readings will not equal the difference between upper and lower base elevations. This discrepancy is of course due to neglect of temperature. But since we do know the difference between upper and lower base elevations, and if we assume that the temperature varies in a straight line between the bases, we can form a proportion."

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4-10-47
Contour Map
Section of Rensselaer, N.Y.
Scale

Thesis 6355
G7 Graves
A survey of part of
the city of Rensselaer,
New York by aerial photo-
graphs with the use of
altimeters.